SECTION 7—GUIDANCE, NAVIGATION, AND VEHICLE CONTROL TECHNOLOGY

OVERVIEW

This section encompasses technologies for both autonomous and cooperative positioning, coordination, and control of military force elements, as noted in the military S&T Plans. Included are technologies for flight management, guidance, and vehicle control. Elements of the technology continue to be improved and adapted to mission needs. This is especially true for the U.S. Global Positioning System (GPS). Navigation is defined as obtaining the present condition or state of the vehicle from sensed values of position and motion. Guidance systems integrate these conditions and produce vehicle control responses. In essence, these technologies are closely coupled and overlap depending on application, which includes WMD. Most of these technologies have dual-use requirements, and all of them are essential for various mission needs. Commercial aircraft accuracy requirements are generally less than those for military aircraft. The trend is for consolidation of various navigation technologies into hybrid systems.

SECTION 7.1—AIRCRAFT AND VEHICLE CONTROL SYSTEMS

OVERVIEW

Flight control systems (FCS) (including Fly-by-Wire and Fly-by-Light) are composed of sensors, computers, actuators, and the other system components dictated by the architecture, methodologies, and algorithms required by the air vehicle (aircraft, RPV, or cruise missile) to perform its intended missions. Similar control systems are used in ground, sea, and space vehicle missions. They function to control the vehicle, including agility and steering, to achieve the desired flight path (e.g., weapon launch windows). The FCS also prevents undesirable aircraft and missile motions or structural loads by autonomously processing outputs from multiple sensors and then providing necessary preventive commands to effect automatic control. Flight path optimization is an FCS procedure that minimizes deviations from a four-dimensional (space and time) desired trajectory based on maximizing performance or effectiveness for mission tasks. Particularly important are evolving adaptive control techniques for integrated control and signature control. Control actuators transform control logic into vehicle responses. New technologies are required to further reduce power and logistic support. Electric actuators are used in small civil aircraft, RPVs, and missiles. They replace conventional hydraulic, pneumatic, and mechanical drive systems in larger, high-performance civil and military aircraft and helicopters.

Table 7.1-1. Aircraft and Vehicle Control Systems Militarily Critical Technology Parameters

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Export Control Reference
Airfoils, Variable Geometry	Fixed wing - external robustness to maximize L/D configured airfoil from supersonic only to include high subsonic region. Helicopter - Dynamically optimized airload distribution on rotors for 50% reduction in acoustic signature and 60% less vibration; Bandwidth of > 3 Hz	Smart materials	Digital air vehicle and control system dynamic computer models; CAD development software; pilot in-the-loop simulators; ground and flight testing of prototype systems; CAD tools for linking design parameters to vehicle dynamic models.	Algorithms and verified data containing actual design parameters (e.g., response, shape, rates).	WA ML 10, 21, 22 WA Cat 7E USML VIII CCL Cat 7E
Controller, Multi-Axis	Cooper-Harper rating of < 3; No pilot induced oscillation (PIO) due to rate limiting	None identified	Digital air vehicle and control system dynamic computer models; CAD development software; pilot in-the-loop simulators; ground and flight testing of prototype systems.	Algorithms and verified data containing actual design parameters (e.g., gains, time constants, limits, thresholds).	WA ML 10, 21, 22 WA Cat 7E USML VIII CCL Cat 7E
Electric Actuators	Output power > 4 hp; Rate > 50 deg/s; Acceleration > 100 inches/sec^2; Bandwidth > 4 Hz	Rare earth magnets; see Materials	Digital air vehicle and control system dynamic computer models; pilot in-the-loop simulators; ground and flight testing of prototype systems; CAD tools for developing power controllers.	Algorithms and verified data containing actual design parameters (e.g., power switching logic, gains, time constants).	WA ML 10, 21, 22 WA Cat 7E USML VIII CCL Cat 7E

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Table 7.1-1. Aircraft and Vehicle Control Systems Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Export Control Reference
FLIGHT CONTROL SYSTEMS, ACTIVE	30% reduction in pilot fatigue in 1-2 Hz region caused by turbulence induced structural oscillations; minimize flutter for aeroelasticity induced airspeed limits; 50% increase in structural fatigue life.	None identified	Air vehicle rigid, flexible and control system dynamic computer models; CAD development software; pilot in-the-loop simulators; ground and flight testing of prototype systems; CAD tools for linking design parameters with flexible vehicle dynamics.	Algorithms and verified data containing actual design parameters (e.g., gains, time constants, limits) for military applications. Automatic verification and validation tools.	WA ML 10, 21, 22 WA Cat 7E USML VIII CCL Cat 7E
FLIGHT CONTROL SYSTEMS, FULL AUTHORITY DIGITAL	Equivalent time delay of < 100 milliseconds; bandwidth of > 3 Hz; Aircraft loss rate per flight of < 1×10^{-5}	None identified	Digital air vehicle and control system dynamic computer models; CAD development software; pilot in-the-loop simulators; ground and flight testing of prototype systems.	Algorithms and verified data containing actual design parameters (e.g., gains, time constants, limits). Automatic verification and validation tools.	WA ML 10, 21, 22 WA Cat 7E USML VIII CCL Cat 7E
FLIGHT CONTROL SYSTEMS, MULTI-DISCIPLINED INTEGRATED	Equivalent time delay of < 100 milliseconds; Bandwidth of > 3 Hz; Time to identify structural modes < time to double amplitude	None identified	Integrated air vehicle control system, structural and propulsion dynamic computer models; pilot in-the-loop simulators; ground and flight testing of prototype systems; CAD tools for linking individual disciplinary models.	Algorithms and verified data containing actual design parameters (e.g., gains, time constants, limits). Automatic verification and validation tools.	WA ML 10, 21, 22 WA Cat 7E USML VIII CCL Cat 7E
FLIGHT CONTROL SYSTEMS, RECONFIGURABLE	Detect and respond in less than the time to reach double amplitude	None identified	Digital air vehicle and control system dynamic computer models; pilot in-the-loop simulators; ground and flight testing of prototype systems; CAD tools for linking individual disciplinary models.	Algorithms and verified data containing actual design parameters (e.g., gains, time constants, limits). Automatic verification and validation tools.	WA ML 10, 21, 22 WA Cat 7E USML VIII CCL Cat 7D, E

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Table 7.1-1. Aircraft and Vehicle Control Systems Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Export Control Reference
FLIGHT CONTROL SYSTEMS, THRUST VECTORING	Equivalent time delay of < 100 milliseconds; Bandwidth of > 3 Hz; Rate limit > 60 deg/sec	None identified	Integrated air vehicle control system, structural and propulsion dynamic computer models; pilot in-the-loop simulators; ground and flight testing of prototype systems; CAD tools for linking propulsion and vehicle dynamic models.	Algorithms and verified data containing actual design parameters (e.g., gains, time constants, limits). Automatic verification and validation tools.	WA ML 10, 21, 22 WA Cat 7E USML VIII CCL Cat 7D, E
NONCONVENTIONAL (OPTICAL/MODELING) AIR DATA SENSORS	Operation > 30,000 ft Covert Air Data with accuracy equivalent to conventional sensors	None identified	Unique computer models and laser velocimetry CAD Development Tools for linking algorithms and aircraft shapes	Compensation algorithms and verified data.	WA ML 10, 21, 22 WA Cat 7E USML VIII CCL Cat 7D, E